Minerals and Hydrocarbons

Introduction

The state owns the minerals located in the bed and waters of GSL as public trust resources. The responsibility to manage the minerals of the lake, and of all sovereign state lands, has been assigned to the DFFSL by statute. The division has specific management responsibilities for minerals of GSL pursuant to Section 65A-10-18 of the Utah Code.

Internal and external scoping conducted by the planning team focused on the DFFSL MLP categories and policies.

Although GSL is renowned for its "salt" (sodium chloride or table salt), its waters actually contain other sodium, potassium (potash), calcium and magnesium salts. GSL contains salt from a variety of sources. Rain and snow in the mountains leached saline materials from soils and rocks and carried it in solution to streams that eventually flow into the lake (Miller, 1949). GSL may be as salty as it is because much of the salt was originally in the waters of Lake Bonneville and was concentrated as those waters evaporated (Trimmer, 1998). In addition, some believe that the lake's salts were leached from deposits of oceanic salt of Jurassic age which crop out extensively in Sanpete Valley within the GSL Drainage Basin (Eardley, 1938). Due to the terminal nature of GSL, salt delivered to it remains in the lake. Water entering the lake escapes by evaporation only. GSL presently contains 4.3 billion tons of salt in its system (Trimmer, 1998).
Other geological resources under and around the lake include mirabilite and epsomite, oil and gas, oolites and quartzite. Oil has been produced at Rozel and West Rozel oil fields and natural gas has been produced at Farmington Bay and Bear River Bay but commercial quantities of hydrocarbons have not yet been discovered.

Mirabilite and Epsomite

The most economically important salts in the lake are table salt, potash and magnesium chloride but mirabilite and epsomite are significant resources which have been produced from the lake. Mirabilite (sodium sulfate) is a mineral that is precipitated from highly concentrated lake brines during the cold winter months. This salt is not stable and redissolves as the brine warms in the spring except where it is enclosed in sediment at the bottom of the lake.

During the construction of the northern railroad causeway in about 1900, a deposit of mirabilite was discovered west of Promontory Point. Eardley (1963b) described the deposit as lying 15 to 25 feet below the bottom of the lake, interbedded with the soft lake-bottom clays, and having a maximum thickness of about 32 feet. The salt bed extends westward about 9.5 miles from a point one mile west of Promontory Point, and is bounded on the east by a fault.

When the pilings were driven during construction of the old Saltair resort on the southern end of the lake, a hard layer of mirabilite-cemented oolites was encountered. This layer was penetrated only by steam-jetting a hole for the pilings. Soon after the pilings were installed, natural recrystallization of the mirabilite solidly cemented the pilings in place. Mirabilite-cemented oolite beds have been found at numerous other places around the lake including: the South Shore Marina, the Antelope-Island Marina and the Morton Salt intake canal on the south end of Stansbury Island. They are probably present at many other areas around the lake. At one time, Great Salt Lake Minerals Corp. (now IMC Kalium Ogden Corp.) produced anhydrous sodium sulfate from winter-precipitated mirabilite. There is no current production of mirabilite.

Epsomite (magnesium sulfate) can be produced by the winter cooling of highly concentrated lake brines, such as those utilized by Magcorp in the production of magnesium metal and chlorine gas. Epsomite is not currently being produced from lake brines.

Rozel Point Oil Field

Naturally oozing tars have been collected from areas near Rozel Point, probably since pre-settlement times.

Shallow wells drilled near surface oil seeps at Rozel Point beginning in the early 1900s produced a small amount of oil from a fractured, Tertiary basalt reservoir. The field area lies on mudflats at the edge of the lake and is submerged at times of high lake levels. There are currently no active wells in the Rozel Point oil field. Cumulative production (to 1993) is 2,665 barrels of oil (Kendell, 1993a). The oil is thick with a high sulphur content making it difficult to produce and refine. Rozel Point field is discussed by Heylmun (1961b), Eardley (1956 and 1963a) and Kendell (1993a).

West Rozel Oil Field

Amoco Production Company drilled 15 wells in GSL, utilizing a floating barge-mounted drill rig, from mid-1978 to 1981. The drilling resulted in the discovery of the West Rozel field, a seismically defined structural feature, three miles west-southwest of the Rozel Point oil field. The structure is a faulted anticline about three miles long and more than a mile wide, covering about 2,300 acres. The discovery well produced two to five barrels of oil per hour during production testing from perforations located 2,280 to 2,410 feet below surface in Tertiary basalt. Cumulative production (to 1993) is 33,028 barrels of oil (Kendell, 1993b). The oil is very thick and high in sulfur, making it difficult to produce and refine. West Rozel is discussed by Bortz (1983 and 1987), Bortz and others (1985) and Kendell (1993b).

Additional Oil Shows

Additional oil shows were found in samples collected by Amoco during drilling in the south arm of the lake.

Farmington Gas Field

The Farmington gas field was discovered in 1891 near the shore of GSL about three miles southwest of Farmington. One well produced at a rate of 4.9 million cubic feet of gas per day from a depth of 850 feet. In 1985 a pipeline was built from the field to Salt Lake City and provided gas for 19 months until the gas was depleted or the wells sanded up. It is estimated that the field produced 150 million cubic feet of gas at a rate of 8.5 million cubic feet per month. The

Farmington gas field is discussed by Heylmun (1961a).

Bear River Gun Club

Natural gas has often been encountered while drilling shallow water wells on the Bear River delta. A water well drilled by the Bear River Gun Club was converted to gas production and provided natural gas for private use for many years until the well blew out. When attempts were made to plug the well, the gas flow cut away from the well bore and blew out through the soil. It took several days to control the flow which was estimated to be as large as a million cubic feet a day. There has never been any attempt to commercially exploit the gas resource from the delta.

Oolites

Oolitic sands are an unusual sediment type found in and around GSL at numerous locations. They are rounded, light-colored carbonate grains and range in shape from nearly spherical to cylindrical. Their surfaces are usually smooth, like a miniature pearl. The size of oolites ranges from 0.015 to 1.5 millimeters, with the average size being about 0.31 millimeters. The chemical composition of the outer shell consists mainly of calcium carbonate, though some calcium-magnesium carbonate (dolomite) is also present. The nucleus or central core is usually a mineral fragment or a brine-shrimp fecal pellet.

Some of the areas in which oolites are found include: (1) the west side of Stansbury Island in Stansbury Bay and the north end of the island extending northward past Badger Island, where beds up to 18 feet thick have been measured; (2) around Antelope Island, and especially in the area of the Bridger Bay bathing beaches, and (3) the southern shores of the lake.

Oolites have been used by Magcorp (and their facilities' prior owners) to neutralize the acidic gases produced during the processing of magnesium chloride brines into magnesium metal, and to produce calcium chloride which is used in the brine-desulfation process and as an industrial chemical. Oolites are also used as flux in mining operations and could also be used in most applications where limestone is used. Small amounts of oolitic sand are used to dry flowers.

Bioherms

Calcareous assemblages of flat, mounded algal deposits are called bioherms. These structures form as a result of calcium and magnesium carbonate by the blue-green colonial algae *Aphanothece packardii*. These unicellular algae are the most predominant algal bioherm builders. Bioherms are found in shallow water and near shore environments, where wave activity and subsequent circulation is strong, but algae must have a permanent base for attachment. Bioherms range from several inches to up to 12 feet deep. Bioherms are found along Stansbury Island, the north end of Antelope Island and along the west side of the Promontory Range (Eardley, 1938 and Cohenour, 1966).

Quartzite

Since about 1996 quartzite has been quarried on BLM land near the southwest end of Stansbury Island by McFarland Hullinger Company. The quartzite is sold to KUC for flux to assist copper smelting at Kennecott's Salt Lake Valley facility.

Mineral Industry Overview

Salt extraction is one of Utah's oldest industries and salt has been harvested from the waters of GSL for over 100 years (Miller, 1949). In addition, magnesium metal, chlorine and potassium salts are harvested through extraction processes. These newer industries began in the 1970s. Currently, all major ions contained in the lake water are extracted by solar evaporation in large pond systems (Trimmer, 1998).

There are currently six companies in the GSL minerals industry. These include IMC Kalium Ogden Corp., Magcorp, Cargill Salt, Morton Salt, IMC Salt and North Shore Limited (Appendix F, Exhibits 3 and 4). In 1997, existing aggregate data from DWRi indicate that in excess of 31 billion gallons of water were pumped from GSL by mineral harvesting companies (Hudon, 1998). Sodium chloride (NaCl, or table salt) is the first salt to be precipitated out as lake brines are concentrated, and it is either sold or is a waste product, depending on the focus of each company (Trimmer, 1998).

Magcorp produces magnesium metal from lake water at its electrolytic plant in Tooele County. Chlorine gas is also produced. The plant has a capacity to produce 40,000 metric tons of magnesium metal at 99.9 percent purity annually and is the fourth largest magnesium plant in the world as of 1996. Magcorp represents 28 percent of primary U.S. magnesium capacity (Kramer, 1998a). Magcorp sells some potassium-magnesium salts to IMC Kalium Ogden Corp. (Trimmer, 1998 and U.S. Bureau of Mines, 1996).

Morton and Cargill produce only sodium chloride and return bitterns, the concentrated brine that remains after sodium chloride has crystallized, to the lake. IMC Salt is the largest salt producer on the lake and buys salt from IMC Kalium Ogden Corp. IMC produces magnesium and potassium salts, primarily sulfate of potash (K_2SO_4) rather than muriate of potash (KCl). Sulfate of potash is a higher value product than KCl. IMC Kalium Ogden Corp. produces minerals such as kainite, schoenite and carnallite in its solar ponds which are then processed to remove magnesium, chloride and sodium ions, leaving potassium sulfate. Also, under certain conditions, potassium chloride is added directly to the process where it undergoes a base conversion into potassium sulfate. A significant portion of the sulfate of potash is exported to other countries. This company retains and sells the magnesium chloride brine, but flushes excess sodium chloride and some of the low-grade magnesium and potassium salts back into the lake. Sodium chloride build-up on evaporation pond floors is a problem for both IMC Kalium Ogden Corp. and Magcorp, although IMC is able to return some waste salts to the lake (Trimmer, 1998 and Gwynn, 1998b).

North Shore Limited produces magnesium chloride brines through solar evaporation. This product is sold for nutritional supplements (Trimmer, 1998) (Table 10).

Table 10. Mineral Table

Company	Production
IMC Kalium Ogden Corp.	Magnesium and Potassium Salts ($MgCl_2$, K_2SO_4)
Magnesium Corporation of America	Magnesium Metal (Mg), Chlorine Gas (Cl)
Cargill Salt	Salt (NaCl)
Morton Salt	Salt (NaCl)
IMC Salt	Salt (NaCl)
North Shore Limited	Magnesium Brines ($MgCl_2$)

(Trimmer, 1998 and Gwynn, 1998b)

Production Trends

The salt industry is characterized by high tonnage volumes at relatively low unit values and a product which is harvested far from markets. These products face intense competition within the industry both nationally and internationally (GSLTT and DSLF, 1995). Potassium sulfate is produced at a relatively high volume with higher value per ton, while magnesium metal is produced at a relatively low volume with a high value per ton (Trimmer, 1998). The estimated average price per metric ton of K_2O in 1997 is $140 (Searls, 1998). The estimated average price per metric ton of magnesium metal in 1997 is $2,700 (Kramer, 1998a).

Harvesting is also vulnerable to weather conditions and lake level changes. Cool and wet weather slows evaporation and concentration processes. Both low and high lake levels create problems for the mineral extraction industries. When lake levels are low, intake canals to pumps must be dredged and the pumps may need to be repositioned into deeper water (GSLTT and DSLF, 1995).

High lake levels, as experienced in the mid-1980s, are much more critical to the salt industries than low levels, due to the dilution of feed brines. The economic impact of increased erosion of dikes, dike failure and rebuilding or reinforcing of dikes at high lake levels can also cost millions of dollars (GSLTT and DSLF, 1995).

As the lake level rises and falls, the strength of the brine falls and rises. This inverse relationship is a result of a relatively fixed amount of dissolved solids within the lake coupled with a fluctuating amount of water. When inflow exceeds evaporation, the lake level rises and the extra water dilutes the lake brine. Dilute brine conditions require larger pond areas for a given tonnage of salt production. With a low lake level, brine strength is higher and therefore pumping and pond area requirements are lower for a given tonnage of salt, therefore producing a greater yield. This inverse relationship is particularly applicable to the south arm of the lake, although under some circumstances, similar impacts can result in the north arm of the lake as well (GSLTT and DSLF, 1995).

Salt and brine-derived products are the largest contributors to the value of industrial minerals in Utah. The production of salt and brine-derived products is expected to continue to expand over the next several years (U.S. Bureau of Mines, 1996). For instance, IMC Kalium Ogden Corp., the largest potassium sulfate producer in North America, plans to double current production (Warnick, 1998).

Value of Production

Because there are only six companies on the lake which harvest minerals, and only five mineral commodities are harvested, data on extraction must be presented in aggregate form. Therefore instead of reporting a unit value of the product, this section emphasizes the overall value of production of the minerals harvested. Although the dollar amounts of value of production of minerals extracted is held in confidence by DFFSL, general trends can be noted.

Overall, the value of production of potassium and magnesium salts has increased more than 12-fold since production began in 1973. The value of production of magnesium metal has increased 31-fold since production began in 1974, and the value of production of salt has increased 17-fold since 1970. These increases have not been steady however, as the value of production in all three categories declined periodically, particularly from 1986 to 1989 due to years of flooding. In total, minerals extraction from GSL amounted to a value of production of $231,611,752 in 1997 (Trimmer, 1998) (Figure 14).

Solar salt produced from GSL represents a significant and increasing share of total domestic solar salt production. The remainder of solar salt produced in the U.S. is primarily from California with some production from New Mexico. Solar salt competes in regional markets with rock salt for chemical and industrial, water conditioning and agricultural uses. Nationwide, the consumption of rock salt is four times that of solar salt. However, USGS data show that these markets are regional and, with respect to road salt, local. Solar salt dominates in western markets and appears to be increasing in certain Midwestern markets for certain end uses. DFFSL believes that the growth of regional solar salt markets, in

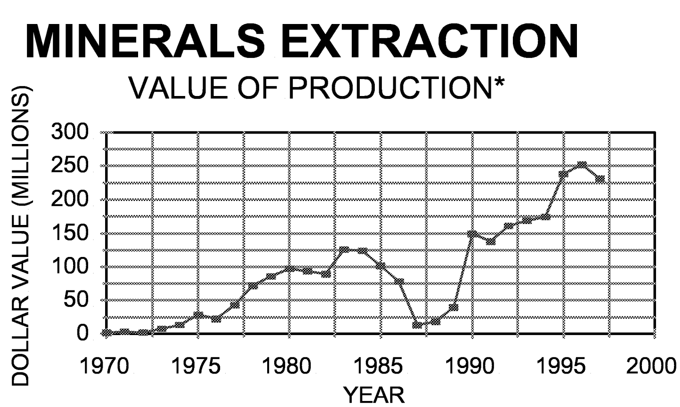

Figure 14 (Source: Utah Division of Forestry, Fire and State Lands)
* not adjusted for inflation

which Utah producers compete, could continue to grow at three percent per year over the next five years. This amounts to approximately 50,000 tons per year (Trimmer, 1996).

Production of magnesium metal in the U.S. declined by six percent in 1996 from 1995. World magnesium oversupply and high prices were primarily responsible. For the first time in 20 years, the U.S. imported more magnesium than it exported. However, the U.S. continued to lead the world in production and production capacity of primary magnesium (Kramer, 1998a). Utah magnesium production remained steady in 1996 while prices declined, primarily due to increased foreign competition (U.S. Bureau of Mines, 1996). Magnesium metal is used for aluminum alloying, diecasting, and automotive applications. However, demand for magnesium used in aluminum alloying dropped in 1996 and several U.S. auto manufacturers canceled some programs to incorporate more magnesium diecastings into domestic passenger vehicles due to rapidly changing magnesium costs (Kramer, 1998a).

The outlook for global use of magnesium diecastings in automotive applications is expected to continue to grow at 15-20 percent average annual growth rate. North America and Europe are expected to be the areas with largest growth. Although magnesium prices declined in 1996 through June 1997, they began to increase slowly from mid-year. Price fluctuations were not as widely varied as in recent history. From 1993 to 1995, prices fluctuated from $2,260 to $4,138 per metric ton (Kramer, 1998a).

U.S. production of magnesium compounds increased in 1996. Magnesium chloride was used mainly as a chemical intermediate. Magnesium chloride brines were used principally for road dust and ice control. $MgCl_2$ was used in agricultural, chemical, construction, environmental and industrial applications. Year-end magnesium compound prices in 1996 did not change from those at year-end 1995 (Kramer, 1998b).

The term potash denotes a variety of mined and manufactured salts, all containing the element potassium in water soluble form. The general term potash also includes potassium sulfate (K_2SO_4), which is produced in Utah (Searls, 1998 and Trimmer, 1998). Domestic potash production comes from New Mexico, Utah and California. Because it is a source of soluble potassium, potash is used primarily as an agricultural fertilizer. U.S. potash sales were approximately 88 percent to the fertilizer industry and approximately 12 percent to the chemical industry. Production of all types and grades of potash in the U.S. declined in 1996. Sales of all types and grades of U.S.-produced potash were unchanged from 1995 to 1996. Potash consumption was only slightly above the 1995 level in 1996 (Searls, 1998).

Royalties on State Minerals

Prior to February 1997, Cargill and Morton paid a $0.10 per ton royalty to DFFSL on salt extraction, while IMC's predecessor paid an *ad valorem* royalty of approximately two percent of the value of the salt. Currently, Cargill and Morton pay a $0.10 per ton royalty to DFFSL, with an additional amount paid into an escrow account which is controlled by the companies. DFFSL, which administers mineral leasing on

GSL, has adjusted the royalty rate to \$0.50 per ton to be implemented over the next five to eight years. DFFSL reached a settlement with Morton Salt for a buyout of its outdated royalty agreement. This action is being contested by other mineral companies (Trimmer, 1998).

IMC Kalium Ogden Corp. pays an ad valorem royalty rate of 1.5-5 percent, increasing over time, on magnesium chloride and potassium sulfate. Magcorp pays a royalty rate of 0.1259-0.41967 percent, increasing over time, on sales of magnesium metal and chlorine gas. In 1986, these companies were allowed to roll back the royalty rate to year one due to flood damage. The royalty rate has continued to advance from this base rate since that time. North Shore Limited pays a royalty of five percent on the value of the brine with a \$5,000 minimum royalty (Trimmer, 1998).

All of the above-listed royalties are put into the restricted Sovereign Lands Management Account. This money must be appropriated by the legislature for any use. To date, these funds have been used for DFFSL's operating costs associated with sovereign lands management and various sovereign lands projects such as the cooperative causeway salinity study with USGS and work related to Utah Lake, the Jordan River Corridor, Bear Lake and the Colorado River (Baker, 1998 and Kappe, 1998).

Royalty Revenues

Royalties paid to the state amounted to \$1,056,367 in 1997. The percent of total value of production paid as royalties declined from 1970 to 1997 with the exception of the period from 1986-1987. Currently, approximately 0.61 percent of total production value is paid in royalties. For those companies that pay a fixed rate on salt harvesting, the percent of total value paid as royalties primarily declined during this time because the selling price increased (Trimmer, 1998).

Additional Research

More research might be useful in the areas of ion depletion and accumulation of waste salts.

Mineral Leasing Plan

On June, 27, 1996, DFFSL published its *Mineral Leasing Plan for Great Salt Lake*. Development of a mineral leasing plan was one of the key recommendations of the 1995 plan. The goals section of the MLP recites:

> "The purpose of the mineral leasing plan for the Great Salt Lake is to guide DSLF [now the Division of Forestry, Fire and State Lands] in accomplishing the following goals:

Integrate minerals resource planning with other resource planning.

> To create a framework for long-term policy direction for minerals management which also has flexibility to respond to the dynamic character of GSL
> To integrate management of GSL's mineral resources with the lake's other resources so that all resources are managed for the health and integrity of the GSL ecosystem
> To identify compatible uses and conflicts among mineral resource development and other resources on GSL and to provide for resolution of conflicts

To monitor impacts of minerals operations and to collect, analyze and use data to maintain health and integrity of the ecosystem, including its mineral resources

To monitor impacts of all diversion, dredging, causeway and diking operations and to collect, analyze and use data to maintain health and integrity of the ecosystem, including its mineral resources

Plan for leasing and efficient development of mineral resources.

To inventory and monitor GSL's mineral resources

To assure wise and diligent development of mineral resources within GSL's boundaries

To provide for the orderly leasing of mineral resources to existing and potential mineral lessees

To receive fair compensation for development and extraction of GSL's various mineral resources

Assert the role of DFFSL as a manager of state-owned lands.

To clearly define sovereign lands for resource users, the public and other resource management agencies

The MLP identifies and evaluates the mineral resources of GSL, impacts of diking and causeways, evaporative pond impacts and constraints, issues and conflicts and the relationships of mineral operations to the other trust resources present on GSL. The plan identifies areas of potential resource conflicts and addresses them by establishing leasing "zones" in the lake and creating mitigation strategies. The plan is the result of a multi-interest, public process conducted over many months.